Süleyman Demirel Üniversitesi
İktisadi ve İdari Bilimler Fakültesi
Y.2003, C.8, S.1 s.49-57.

ECONOMIC ANALYSIS OF HEATING THE PASSIVE SOLAR GREENHOUSE*

Assoc.Prof.Dr.Ahmet AKDENİZ**

ABSTRACT

In this study; firstly passive solar greenhouse improved by Aegean Solar Energy Institute are introduced. Afterwards; the requirement of additional heating energy of this type greenhouse was determined. The life-cycle costing model were developed for economical analysis of the heating of passive solar heated greenhouse. So the numerical, hypothetical, conceptual economical analysis model was created.

Following this; economical analysis of heating of passive solar greenhouse were studied by the model mentioned above. And the best alternative was determined under the meteorological conditions in İzmir/ TURKEY.

Solar passive systems, economic analysis, life-cycle costing concept, net present value.

1. INTRODUCTION

As known, the prices of conventional fuels which is used for heating of greenhouses are rising day by day. As additional, because of the cruses in 1973 and 1979 and the gulf war in 1998, the policy of going towards retainable energy sources especially clean energy sources of solar keep its importance. Depending to these total reasons the experiments about heating houses and greenhouses by using solar energy are going on. We can divide these experiment into two parts. The first one, is the efforts of to increase the effectiveness of solar in classical greenhouses. This type of works, are collected on using of the heat at night which collected day time and save heat loses. The second one as a completely different, planned passive solar greenhouses that isolate outside of the north-side which takes the best solar radiation rate and using the inside as an energy collector. The studies on possibility of using solar energy in agriculture and to increasing the commercial using of solar energy is going on. It is possible to use solar energy effectively in TURKEY which has annual average temperature 17-20 C and the total sunny hours are 2700-3100 hours in Aegean, Mediterranean

---

* This paper was presented in 23rd Conference on R&D in Agricultural Engineering, January,1999 19-20, Gödöllö-Hungary.

** Nine September University, Faculty of Economics and Administrative Sciences, Dept. Of Econometrics Buca-İzmir, Turkey

and south-east Anatolia regions. Except some regions in Black sea region in all regions you can use solar energy effectively.

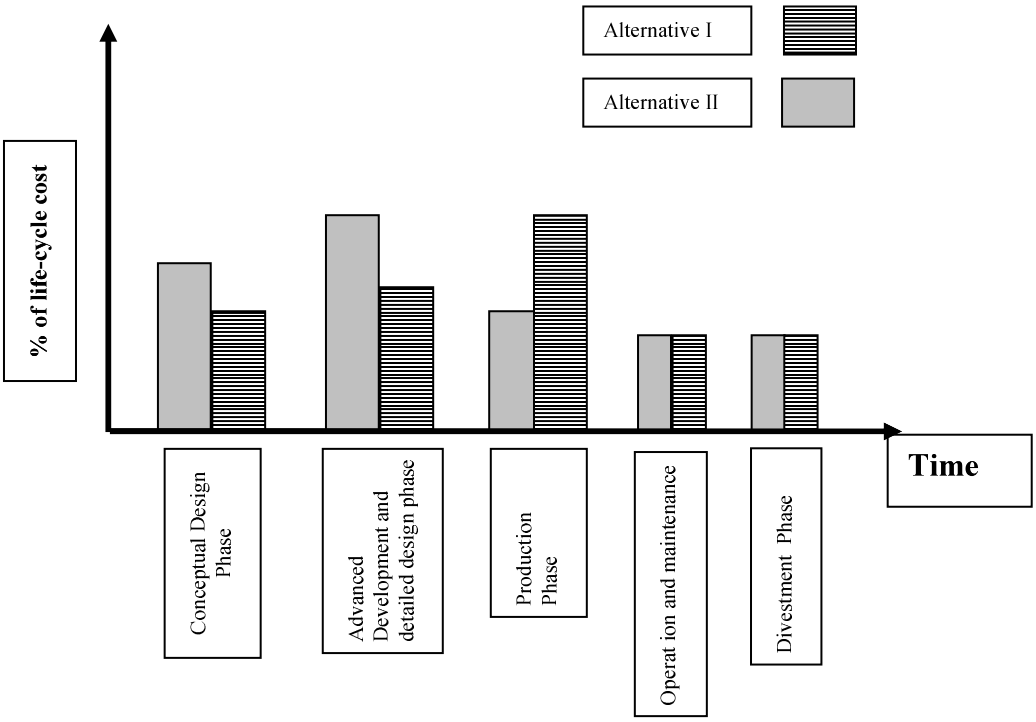
In this study; the passive solar greenhouse will be recognize which developed in Solar Energy Institute of Aegean University the only solar center of TURKEY and following this, economic analysis of heating the passive solar greenhouse will be done.

2. LİFE-CYCLE

2.1. LİFE-CYCLE COSTİNG

Life Cycle cost (LCC) is the total cost of ownership of a product, structure or system over in useful life. The major factors are the cost of acquisition, operation, service, and disposal. The costs were associated with conceptual analysis, feasibility studies, development and design, logistics support analysis, manufacturing, and testing.

The five life-cycle phases which having a project are shown in Figure 1. This Figure 1 is sampled with two alternatives:



Resource : SHTUB, A. “Project Management”, 1994
Figure 1: Cost Classification by the life-cycle Phase

The need for life-cycle costing arises because decisions made during the early stages of a project inevitably have an impact on future outlays. An LCC analysis is designed to help managers identify and evaluate the economic consequences of their decisions. By developing a functional representation relationship of the cost components in terms of to decisions variables, the expected effect of changing any of the decision variables on one our more of the cost components can be analyzed. This situation is depicted in Figure 2, where two alternative technologies are considered. Alternative technology 1 requires lower labor cost for the first unite produced but has a slower learning rate thane that of alternative technology 2. the decision to adopt either alternative technology depends on the number of units required and the cost of capital.

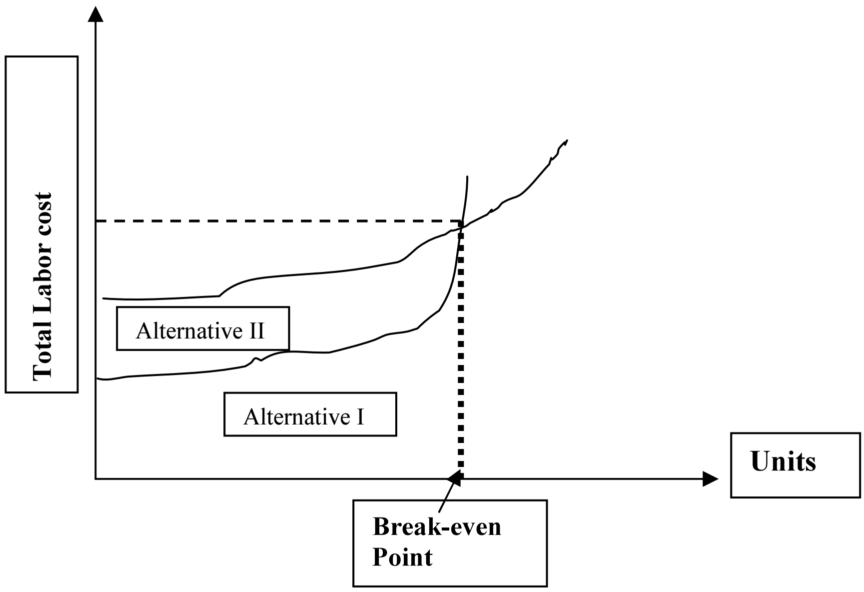


Figure 2: Learning Curves for the Alternative

2.2. Using The Lcc Model

The LCC Model depends on the basis for several types of analyses and decision making:

1- Design Evaluations
2- Evaluation of Engineering change requests
3- Sensivity analysis and risk assessment
4- Logistic Support Analysis
5- Pareto and ABC Analysis
6- Budget and cash flow Analysis

By using a cost estimating relationship, the effect of alternative decisions of the system's life-cycle cost can be analyzed and used as a basis for alternative Evaluation and selection, resource acquisition and management.

3. INTRODUCTION OF THE PASSIVE SOLAR GREENHOUSE

The passive solar greenhouse developed by solar Energy Institute of Aegean University and the construction had been completed in 1985.

The passive solar greenhouse that shown in figure 3, is completely designed by Solar Energy Institute. As you see in figure 3, the passive solar greenhouse has 16.75 m length on East-west direction, 6.67 m on Earth-North direction and the height of the north wall is 7 m and the glass wall on south have a height 2 m. T save the heat loss the north wall is covered with stropor and black painted cups full of water placed inside of this wall which have a shelf type shape and these cups looks to wards the south. To create an air current on north sides of these cups, 1.5 cm empty spaces leaved, between than. By the way of the black painted surfaces of cups absorbs solar energy, Energy turns into heat here. The collected heat passes to the water and stored there. The stored energy used in heating process at nights.

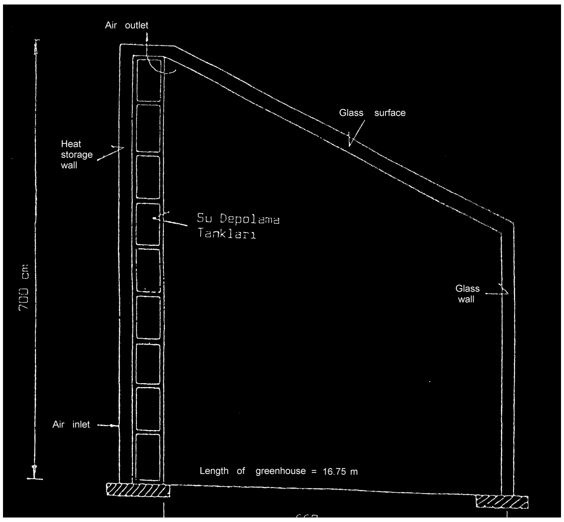


Figure 3. Cross-section of the passive solar greenhouse.

Fresh-air comes in through the bottom side of north-wall and dirty air leave through upper side of this wall. Because of specifications of this, north-wall, it has a heat collecting and storing role. Beside of these ventilation has also a satisfactory role. On the top of the north-wall, there are six ventilation windows, which they have area 12% at ceiling surface area. Greenhouse have two (2 m) (1.62 m) door on east and west which made of galvanized steel profile. For saving the heat loses, in the inside of the greenhouse 2 m height nylon covering system installed. The schematic view of the mentioned greenhouse is shown in figure 4.

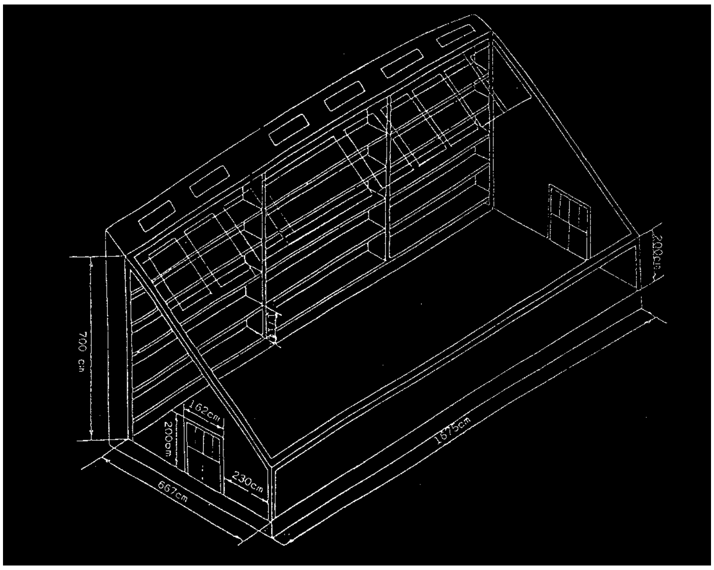


Figure 4. The schematic view of the passive solar greenhouse.

4. THE EXPERIMENTS ON THE PASSIVE SOLAR GREENHOUSE

Experimental measurements had been taken on the passive solar greenhouse which completed in 1985. The inside and outside temperatures had been recorded by using thermograph. The daily average temperature differences in January 1987 are given in figure 5.

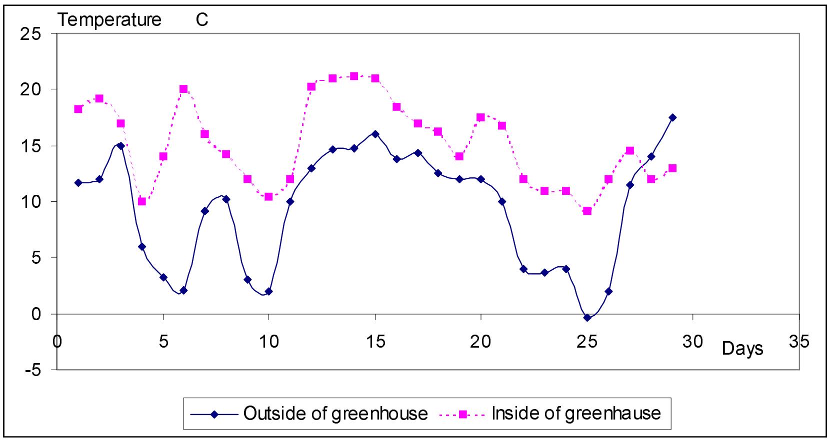


Figure 5. The daily average temperature differences in the passive solar greenhouse.

5. BANANA PRODUCTION IN PASSIVE SOLAR GREENHOUSE

In 1986-1987 winter, after several experimental measurements, ten banana plants were planted in this (16.75 m), (6.67 m) passive solar greenhouse. For heating additional to the solar energy, gas heater without pipes used and 380 liter gas spend. In only one season, 300 kg yield taken, the availability of this system will be examined by economic analysis.

6. ECONOMIC ANALYSIS

Among the many economic analysis methods the "Life-cycle costing method" and as an comparison method the "Net present value method have been chosen for the economic analysis of the solar passive systems used in the present investigation. A quantitative-conceptual-hypothetical economic analysis model has been developed in this work by improving the above mentioned methods. This model has been applied to the both, active and solar passive heating systems altogether six alternatives: Fuel-oil, lignite fired central heating systems and coal fired stove systems and passive solar energy systems supported by Gas and Coal fired stove.

The Properties of the Model :

The life-cycle costing concept is entirely a cost analysis and it consists of the initial investment costs and the operation and maintenance costs which are the costs spent during the whole life time of the above mentioned six alternatives. Since the income does not exist in economic analysis of solar passive systems the net present costs method has been used instead of net present value method, as follows:

$$NCP = \sum_{k=1}^{n} C_k / (1+i)^k$$

Where, ck and i are the costs and the interest rate respectively. The comparison has been made by transferring the whole cost items in to the net present value.

Assumptions of the Model:

1. 7The life time of active systems should be 10 years and of passive solar system used here at least 20 years,
2. The increase in fuel prices have been taken in scenarios a b given below from the 20 years trend curves for the steps of two-year-mean values. The 20-years trend curves have been calculated using last 20-years fuel prices or inflation rates according to the data published by Turkish commerce chamber Istanbul. The scenarios are:

a) Scenario 1: The fuel price increase rates have been taken from the 20-years trend curve.

b) Scenario 2: The fuel price increase rates have been taken equal to the inflation rates.

3. After 10-years life time of active systems the replacements costs have been according to the increase of credit interest rates in both scenarios.
4. In the both scenarios, the net present costs have been calculated using the credit interest rates, beginning with an initial value of 76% and adding 1% for each period of two years.
5. The salvage values have been taken as zero for the six alternatives.

Mathematical Structure of the Model

The symbols used in the mathematical structure are: n_k gives the system life time, n is the comparison period, i means the interest rate; i_{eff} is the effective interest rate; C gives the initial investment costs; A is the annual constant operation costs; C is the replacement costs at the end of 10 years and C_{oh} is the initial auxiliary heat source costs .

According to the relation between the increase rate of the reel prices and the credit interest rates, the net present costs will be calculated, as follows:

a) If, J = 0, i,e., i_{eff} =i, it will be :

$$C_T = C_o + C_{oh} + (P/A,i_o.{}_0m).A_o + (P/F.i_1.m).A_1.(P/F.i_0.m)+(P/A.i_2.m).A_2 (P/F.i_1.m)(P/F.i_o.m) + (P/A.i_3.m).A_3 (P/F.i_2.m)(P/F.i_1.m)(P/F.i_o.m) + (P/A.i_4.m).A_4 (P/F,i_3,m)(P/F.i_2.m)(P/F.i_1.m)(P/F.i_o.m) + (Cr_{10} (P/F.i_4.m)(P/F.i_3.m)(P/F.i_2.m)(P/F.i_1.m)(P/F.i_o.m) + (P/F.i_5.m).A_5 (P/F.i_4.m)(P/F.i_3.m)(P/F.i_2.m)(P/F.i_1.m)(P/F.i_o.m) + (P/A.i_6.m).A_6 (P/F.i_5.m)(P/F.i_4.m)(P/F.i_3\ m)(P/F.i_2.m)(P/F.i_1.m)(P/F.i_o.m)+(P/F.i_7.m) \quad (2)$$

$$A_7 (P/F.i_6.m)(P/F.i_5.m)(P/F.i_4.m)(P/F.i_3.m)(P/F.i_2.m)(P/F.i_1.m)(P/F.io.m) + (P/F.i_8.m)(P/F.i_7.m)(P/F.i_6.m)(P/F.i_5.m)(P/F.i_4.m)(P/F.i_3.m)(P/F.i_2.m)(P/F.i_1.m)(P/F.i_o.m) + (P/A.i_9.m).A_9 (P/F.i_8.m)(P/F.i_7.m)(P/F.i_6.m)(P/F.i_5.m)(P/F.i_4.m)(P/F.i_3.m)(P/F.i_2.m)(P/F.i_1.m)(P/F.i_o.m) - (P/F.i_9.m) H (P/F.i_8.m)(P/F.i_7.m)(P/F.i_6.m)(P/F.i_5.m)(P/F.i_4.m)(P/F.i_3.m)(P/F.i_2.m)(P/F.i_1.m)(P/F.i_o.m)$$

were m=2, P is the present value of money. F is the future value of money and A gives the annual constant operation and maintenance costs.

b. If, J≠ 0, i.e, $i_{eff} \neq i$, the effective interest rate given by Eq. (3) will be insert in Eq. (2) As the interest rate, i. Here, the number of period, p. will take the vales from zero to 9. i.e., p=0 ; 1;... 9. Equation (3) is given below:

$$(i_{eff})_p = i_p - (j/j+1)_p$$

The data for the Eqs. (2) and (3) have been calculated by means of a computer program which takes in to account the heat losses and the additional heat sources and given in Table 1.

Table 1. Data for Equations (2) and (3)

Alternatives	**Initial Investment Cost (C_o) (Million TL)**	**Amount**	**Annual running cost (A_o) (Million TL)**
Solar Passive Systems			
Cehtral Heating Systems	518.86	6528 lt/year	527.62
Fuel-Oil	526.48	19382 kg/year	498.78
Lignite	183.62	18940 kg/year	471.62
Coal store system			
Passive Solar Energy			
Supported by stove:	1542.85	380 lt/year	76.35
Gas	1466.35	2563 kg/year	63.88
Coal			

6. RESULTS

The results of calculations according to Equations (2) and (3) and Table 1. Give that the minimum net present costs belongs to the solar passive system therefore the solar passive system is the best choice of six alternatives in both scenarios, Table 2.

Table 2. Results of computer program.

Scenario No	The best alternative	2^{nd} alternative	3^{rd} alternative
1 and 2	Passive Solar Energy Supported by coal stove	Passive Solar Energy Supported by gas stove	Coal stove system

Solar passive systems will be recommended for the heating of greenhouse in TURKEY, because they are economical competitive.

LITERATURE

1. AKDENİZ,H.A. "Optimum Bina Isıtma Sisteminin Seçiminde Alternatif Kararların Ekonomik Analizi". Ege Üniversitesi Güneş Enerjisi Enstitüsü Doktora Tezi, 1989.
2. AKDENİZ,H.A. "Güneş Enerjili Sistemlerin İrdelenmesinde Kullanılan Ekonomik Analiz Modeli" Ege Üniversitesi Güneş Enerjisi Enstitüsü Dergisi, Cilt 1.Sayı: 1. 1989.
3. ATAGÜNDÜZ,G. "Güneş Enerjisi Temelleri ve Uygulamaları", Kitabı.
4. ATAGÜNDÜZ,G."Heat Transfer Calculations and Design a new type Solar Greenhouse". I.v.Savjetovanje O Energisi, u Okvıru Rast-Yu 82, Opatija, 20-22, X, 1982, Jugoslavıje.
5. ÇAKIN,Z.M. "Seraların Isı Transferi Yönünden İncelenmesi ve Seralarda Güneş Enerjisinin Etkin Kullanımı", Yüksek Lisans Tezi, E.Ü.Güneş Enerjisi Enstitüsü, 1982.
6. FABRYCKY,W.J.; THUESEN,G.J. "Economic Decision Analysis", 2. Ed. Englewood Cliffs, Prentice-Hall, Inc.
7. 7..KREIDER,J.F.;KREITH,F. "Solar Heating and Cooling Engineering", Practical Design and Economics, Hemisphere Publishin Corporation, Washington, 1975.
8. LAWRENCE,K.; MCRAE., A.; ALLEY,S. "Energy Conservation" Aspen Systems Corporation Rockvaile, Maryland, 1980.
9. LUNDE,P.J. "Solar Thermal Engineering Space Heating and Hot Water Systems", 1980,
10. SHTUB, A.; BARD J, F. ; GLOBERSON, S. "Project Management", Upple Saddle River, New-jersey, 1994.
11. BLANCHARD, B. S., Design and Manage to life Cycle-cost, Matrix Press, Chesterland, OH, 1978.
12. Center for Policy Alternatives, Massachusetts Institute of Technology , "Consumer Durables: Warranties, Service Contracts and Alternatives," Analysis of Consumer Product and Warranty Relationships, Vol.IV, Cambridge,MA,1978.